INJECTION LANCE

Field of the Invention

[0001] The present invention relates to devices used in the processing of molten metals, and more particularly, to injection lances for purging and treatment of a molten metal.

Background of the Invention

[0002] Various processes have been developed to treat molten metals (e.g., liquid steel) after primary melting and refining, to improve the purity and quality of the metal compositions. The primary melting and refining processes occur in vessels such as a basic oxygen furnace (BOF) or an electric arc furnace (EAF). Treatment of the molten metal after primary melting and refining is often done in a ladle, and is commonly referred to as "secondary metallurgy," "ladle metallurgy," or in the case of liquid steel "secondary steelmaking."

[0003] A commonly used ladle metallurgy technique involves the use of an injection lance to stir, trim and rinse the molten metal. A typical injection lance is generally comprised of a metal center pipe surrounded by a refractory shell. The refractory shell is comprised of a low cement castable refractory material having an alumina content ranging from 70% to 96%. The injection lance is inserted into molten metal, and a gas (e.g., argon) is introduced into the molten metal. In this regard, gas is forced into the center pipe, and diffuses into the molten metal through a porous nozzle tip. Alternatively, some injection lances are configured with an open-ended pipe in substitution of the porous nozzle tip. This type of injection lance can be used to introduce gas into the molten metal, as well as introduce various powdered/granular metallurgical agents into the molten metal with the gas. The metallurgical agents may include, but are not limited to, lime, calcium silicide, and ferromanganese.

[0004] Use of injection lances provides several benefits that include: (a) enabling the temperature of the molten metal to be adjusted, (b) homogenizing the molten metal, (c) promoting the mixing of slag and metal for operations such as desulphurization, (d) efficiently mixing alloys into the melt to adjust the chemical composition of the molten metal, and (e) enhancing flotation of inclusions into the slag layer.

[0005] The primary function of the refractory shell is to protect the metal center pipe from corrosion, erosion and wear caused by exposure to the slag layer and the molten metal. Several problems are associated with the erosion and wear of a refractory shell. One such problem occurs when certain areas of the refractory shell wear more than other areas of the refractory shell. This uneven wear is known as preferential wear, and occurs where the injection lance passes through the slag layer. Preferential wear can also occur at the tip of the injection lance, where gases exit from the center pipe into the molten metal. Preferential wear causes damage to the injection lance such that it must be discarded, even though considerable castable refractory material may remain in other areas of the refractory shell.

[0006] Various attempts have been made to address preferential wear of the refractory shell. These attempts have included using a more wear resistant castable refractory material in those portions of the refractory shell that exhibit high wear. For example, more wear resistant castable refractory materials that have been used in high wear portions of the refractory shell include materials having an increased alumina content or a spinel castable material. However, use of these more wear resistant castable refractory materials has not solved the problem of preferential wear of the refractory shell.

[0007] Another attempt to solve the preferential wear problem has been to use magnesia-carbon sleeves to form the portion of the refractory shell at the slag line. A magnesia-carbon sleeve is a pressed article having a cylindrical shape. The sleeve surrounds the center pipe, with appropriate materials located between the sleeve and the center pipe. While magnesia-carbon sleeves have exhibited resistance to attack by the slag, the magnesia-carbon sleeves have a tendency to crack and fall off as a result of thermal shock when the injection lance is inserted into the molten metal. Accordingly, magnesia-carbon sleeves do not provide an injection lance with satisfactory performance.

[0008] Another problem with a refractory shell made with a castable refractory material is that it can be difficult to form. A common technique for forming the refractory shell is to place the center pipe in a vertical direction and to surround it with an exterior mold. The castable refractory material is then cast into the space between the center pipe and the mold. Casting problems may be encountered due to the large

longitudinal dimension of the injection lance, in relation to the space between the center pipe and the mold.

[0009] The present invention overcomes the abovementioned problems, as well as other problems associated with prior art injection lances.

Summary of the Invention

[0010] In accordance with the present invention, there is provided an injection lance for use in a metallurgical operation, the injection lance comprising: (a) at least one body section having a first center pipe and a first refractory shell surrounding the first center pipe; (2) an end section having a second center pipe and a second refractory shell, said end section joined to one of said at least one body sections, wherein at least one of the first and second refractory shells is formed of a refractory composition that is isopressed.

[0011] An advantage of the present invention is the provision of an injection lance suitable for injecting gases into molten metal located in a metallurgical vessel.

[0012] Another advantage of the present invention is the provision of an injection lance suitable for injecting powdered/granular metallurgical agents into molten metal located in a metallurgical vessel.

[0013] Another advantage of the present invention is the provision of an injection lance, having better wear resistance, durability and service life, than injection lances known heretofore.

[0014] Still another advantage of the present invention is the provision of an injection lance having greater resistance to slag, abrasion, corrosion and thermal shock, than injection lances known heretofore.

[0015] A still further advantage of the present invention is the provision of an injection lance comprised of a refractory composition having a greater carbon content than injection lances known heretofore.

[0016] Yet another advantage of the present invention is the provision of an injection lance that is more cost effective to manufacture than injection lances known heretofore.

[0017] These and other advantages will become apparent from the following description of a preferred embodiment taken together with the accompanying drawings and the appended claims.

Brief Description of the Drawings

[0018] The invention may take physical form in certain parts and arrangement of parts, a preferred embodiment of which will be described in detail in the specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

[0019] FIG. 1 is a partially sectioned, elevational view of an injection lance, illustrating a preferred embodiment of the present invention;

[0020] FIG. 2 is an enlarged cross-sectional view of a body section of the injection lance shown in Fig. 1;

[0021] FIG. 3 is an enlarged cross-sectional view of an end section of the injection lance shown in FIG. 1;

[0022] FIG. 4 is a sectional view of the injection lance taken along lines 4-4 of FIG. 3; and

[0023] FIG. 5 is an enlarged cross-sectional view of an alternative embodiment of an end section of the injection lance.

Detailed Description of a Preferred Embodiment

[0024] Referring now to the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only, and not for the purpose of limiting same, FIG. 1 shows an injection lance 10, illustrating a preferred embodiment of the present invention. In the embodiment shown, injection lance 10 is generally comprised of a plurality of like body sections 20A, 20B, and 20C, and an end section 120. Body sections 20A, 20B, and 20C, and end section 120 are joined to each other to form injection lance 10, as will be described in detail herein.

[0025] Referring now to FIG. 2, body section 20A is shown in detail. As indicated above, body sections 20B and 20C are generally the same as body section 20A. Accordingly, only body section 20A will be described in detail. Body section 20A includes a center pipe 30 and a refractory shell 60. Refractory shell 60 surrounds center pipe 30, as best seen in FIG. 2.

[0026] In the embodiment shown, center pipe 30 is a tubular structure having an inner surface 32, an outer surface 34, a first end 38, a second end 40, and a coupling member 42. In the illustrated embodiment, center pipe 30 is a conventional

pipe formed of a metal or metal alloy, such as steel. However, it should be appreciated that center pipe 30 may alternatively be formed of other suitable materials, including, but not limited to cast iron, copper, bronze, and cast aluminum.

[0027] Inner surface 32 defines an inner passage 36. A plurality of metal anchoring members 50 are fixed to outer surface 34, preferably by welding. Anchoring members 50 include a plurality of arms 52 extending transverse to the longitudinal axis of center pipe 30. In the illustrated embodiment, arms 52 are formed of bent wire arranged in a V-shape. Arms 52 are embedded in refractory shell 60 to facilitate bonding of refractory shell 60 to center pipe 30, as shall be described in greater detail below.

[0028] In a preferred embodiment, first end 38 and second end 40 each define a threaded male fitting, wherein threads 39 are formed on outer surface 34.

[0029] Coupling member 42 has a first end 44 and a second end 46, wherein each first and second end 44, 46 defines a threaded female end. First end 44 is threadingly attached with second end 40, as best seen in FIG. 2. In the illustrated embodiment, coupling member 42 is a conventional coupling made of a material selected from one of the materials described above in connection with center pipe 30.

[0030] As indicated above, refractory shell 60 surrounds center pipe 30. In the illustrated embodiment, refractory shell 60 has a generally cylindrical shape, and is generally coaxial with center pipe 30. Refractory shell 60 has an outer surface 64, an inner surface 66, a male end 70, and a female end 80.

[0031] Male end 70 includes a flat annular surface 72 and a conical projection 74. First end 38 of center pipe 30 protrudes from conical projection 74, exposing threads 39. Female end 80 includes a flat annular surface 82 and a conical recess 84. Coupling member 42 is recessed within conical recess 84 at female end 80. Male end 70 is dimensioned to mate with female end 80. In this manner, body sections 20A, 20B, 20C may be joined together (FIG. 1), as will be described in further detail below.

[0032] As indicated above, anchoring members 50 of center pipe 30 are embedded in refractory shell 60. Anchoring members 50 facilitate the bonding of refractory shell 60 to center pipe 30 by re-enforcing the metal-refractory contact.

[0033] Refractory shell 60 is preferably formed of a refractory composition that is isopressed onto center pipe 30. In accordance with a preferred embodiment of

the present invention, the refractory composition is comprised of the following components:

(a) 65% to 99% by weight of a refractory material selected from the group consisting of: alumina (Al_2O_3), magnesium oxide (MgO), silica (SiO_2), zirconium oxide (ZrO_2), spinel ($MgO \cdot Al_2O_3$) and combinations thereof, wherein the alumina is preferably in the form of tabular alumina, white fused alumina, brown fused alumina, bauxite and combinations thereof;

(b) 1% to 25% by weight of carbon, wherein the carbon is preferably in the form of carbon black, graphite, silicon carbide, other carbon-containing materials, such as powdered pitches, and combinations thereof;

(c) 0% to 15% by weight of an antioxidant selected from the group consisting of: magnesium, aluminum, silicon, boron carbide, elemental boron, other boron-containing compounds, and combinations thereof; and

(d) a resin binder, including, but not limited to, a phenolic resin, resorcinol-formaldehyde resin, epoxy resin, polyvinyl chloride, furan resins, urea-formaldehyde resins, polyurethane resins, silicone resins, polyacrylic resins, vinylacetate resins, polyamine resins, polybutadiene resins, or combinations thereof. The preferred resin binder is phenolic resin.

[0034] The foregoing components are combined to form a refractory granular mix. Furthermore, it should be understood that in addition to the aforementioned components, one or more additives may be included to enhance corrosion or thermal shock resistance. The additives may include, by way of example and not limitation, metallic or non-oxide powders and aggregates, other suitable oxides, and metal (e.g., stainless steel), organic or carbon fibers.

[0035] The steps for forming refractory shell 60 of each body section 20A, 20B and 20C, by an isostatic pressing process, are basically as follows: (a) preparing a rubber mold conforming to the shape (i.e., outer profile) of refractory shell 60; (b) placing center pipe 30 (including anchoring members 50) inside the rubber mold; (c) filling voids (gaps) inside the rubber mold with a granular mix of the refractory

composition described above; (d) closing the rubber mold, and submerging the rubber mold into a liquid pressing medium in an isostatic pressing chamber; (d) pressurizing the liquid pressing medium in the pressing chamber to a pressure of approximately 15,000 psi or higher to fully densify the refractory composition; (e) maintaining the desired pressure for a suitable period of time; (f) reducing the pressure, and removing the newly-formed body section from the rubber mold; (g) placing the newly-formed body section in a curing oven; (h) curing at a temperature of approximately 300 °F or greater, for a suitable period of time; and (i) reducing the temperature of the curing oven to cool the newly-formed body section, and removing the newly-formed body section from the curing oven. It should be appreciated that isopressing facilitates the use of carbon with the refractory material.

[0036] Referring now to FIG. 3., there is shown end section 120. End section 120 includes a center pipe 130, a plurality of rods 160, a nozzle assembly 180, and a refractory shell 260. Refractory shell 260 surrounds center pipe 130, as shown in FIG. 3. In the embodiment shown, center pipe 130 is a tubular structure having an inner surface 132, an outer surface 134, a first end 138, and a second end 140. In the illustrated embodiment, center pipe 130 is a conventional pipe made of a material selected from one of the materials described above in connection with pipe 30.

[0037] Inner surface 132 defines an inner passage 136. A plurality of metal anchoring members 150 are fixed to outer surface 134, preferably by welding. Anchoring members 150 include a plurality of arms 152 extending transverse to the longitudinal axis of center pipe 130. In the illustrated embodiment, arms 152 are formed of bent wire arranged in a V-shape. Arms 152 are embedded in refractory shell 260 to facilitate bonding of refractory shell 260 to center pipe 130.

[0038] In a preferred embodiment, first end 138 defines a threaded male fitting, wherein threads 139 are formed on outer surface 134.

[0039] Referring now to FIGS. 3 and 4, rods 160 are radially disposed around center pipe 130, according to the illustrated embodiment. Each rod 160 includes a first portion 162 and a second portion 164. First portion 162 is fixed to outer surface 134 of center pipe 130, preferably by welding. Second portion 164 is spaced from outer surface 134 of center pipe 130, and includes a distal end 166. Annular rings 170 are located between outer surface 134 of center pipe 130 and second portion 164 of rod 160 to maintain the spacing between second portion 164 and outer surface 134. In

a preferred embodiment, annular rings 170 are welded to center pipe 130 and rods 160.

[0040] Distal end 166 of each rod 160 extends beyond second end 140 of center pipe 130, and are spaced to capture a porous nozzle tip 182 of nozzle assembly 180, described in detail below. In this regard, distal ends 166 are dimensioned to receive and hold porous nozzle tip 182, as shown in FIG. 3.

[0041] Nozzle assembly 180 is generally comprised of porous nozzle tip 182 and pipe 190. Nozzle tip 182 includes an inner surface 184, a side surface 186 and an outer surface 188. Nozzle tip 182 has a generally conical shape, and is preferably made of a porous refractory material.

[0042] Pipe 190 has a first end 192 and a second end (not shown) that is embedded in porous nozzle tip 182. Pipe 190 defines an inner passage 194. In the illustrated embodiment, pipe 190 is formed of a metal or metal alloy, such as steel. However, it should be appreciated that pipe 190 may alternatively be formed of other suitable materials, including, but not limited to cast iron, copper, bronze, and cast aluminum. As shown in FIG. 3, inner passage 136 of center pipe 130 is dimensioned to receive pipe 190. In accordance with a preferred embodiment, pipe 190 is generally coaxial with center pipe 130, and extends substantially into inner passage 136. Preferably, first end 192 of pipe 190 is located in close proximity to first end 138 of center pipe 130, as shown in FIG. 3.

[0043] As indicated above, refractory shell 260 surrounds center pipe 130. In the illustrated embodiment, refractory shell 260 has a generally cylindrical shape, and is generally coaxial with center pipe 130. Refractory shell 260 has an outer surface 264, a male end 270 and a rounded end 280. Male end 270 includes a flat annular surface 272 and a conical projection 274. First end 138 of center pipe 130 protrudes from conical projection 274, exposing threads 139. Male end 270 of end section 120 is dimensioned to mate with female end 80 of body section 20A, as shown in FIG. 1. In a preferred embodiment, rounded end 280 is flush with outer surface 188 of nozzle tip 182.

[0044] As indicated above, arms 152 of anchoring members 150 are embedded in refractory shell 260. Arms 152 facilitate the bonding of refractory shell 260 to center pipe 30.

[0045] In accordance with a preferred embodiment of the present invention, refractory shell 260 is formed of the refractory composition described above in connection with refractory shell 60, and the steps for forming refractory shell 260 are generally the same as the steps for forming refractory shell 60, as described in detail above.

[0046] An alternative end section 320 will now be described with reference to FIG. 5. End section 320 is suitable for introducing a gas, or a gas and one or more powdered/granular metallurgical agents, into the molten metal, by providing a continuous passageway through the length end section 320, as will be described in further detail below. End section 320 includes a center pipe 330, and a refractory shell 360. Refractory shell 360 surrounds center pipe 330.

[0047] In the embodiment shown, center pipe 330 is a tubular structure having an inner surface 332, an outer surface 334, a first end 338, and a second end 340. In the illustrated embodiment, center pipe 330 is a conventional pipe made of a material selected from one of the materials described above in connection with pipe 30.

[0048] In a preferred embodiment, center pipe 330 extends the length of end section 320 to define a continuous passageway therethrough. First end 338 of center pipe 330 defines a threaded male fitting, wherein threads 339 are formed on outer surface 334. Second end 340 of center pipe 330 includes an opening 390 defining an open-ended tip.

[0049] Inner surface 332 defines an inner passage 336. A plurality of metal anchoring members 350 are fixed to outer surface 334, preferably by welding. Anchoring members 350 include a plurality of arms 352 extending transverse to the longitudinal axis of center pipe 330. In the illustrated embodiment, arms 352 are formed of bent wire arranged in a V-shape. Arms 352 are embedded in refractory shell 360 to facilitate bonding of refractory shell 360 to center pipe 330.

[0050] As indicated above, refractory shell 360 surrounds center pipe 330. In the illustrated embodiment, refractory shell 360 has a generally cylindrical shape, and is generally coaxial with center pipe 330. Refractory shell 360 has an outer surface 364, an inner surface 366, a male end 370 and a second end 380. Male end 370 includes a flat annular surface 372 and a conical projection 374. First end 338 of center pipe 330 protrudes from conical projection 374, exposing threads 339. Male end 370 of end section 320 is dimensioned to mate with female end 80 of body section

20A. In the illustrated embodiment, second end 380 has a generally planar surface 382. However, it should be appreciated that surface 382 may also be curved or have an alternative geometric configuration.

[0051] As indicated above, arms 352 of anchoring members 350 are embedded in refractory shell 360. Arms 352 facilitate the bonding of refractory shell 360 to center pipe 330.

[0052] In accordance with a preferred embodiment of the present invention, refractory shell 360 is formed of the refractory composition described above in connection with refractory shell 60, and the steps for forming refractory shell 360 are generally the same as the steps for forming refractory shell 60, as described in detail above.

[0053] It is contemplated that the refractory composition used for each body section 20A, 20B, 20C, and end section 120 (or end section 320) may be selected from different types of refractory compositions. In this regard, refractory compositions having superior wear-resistance properties may be used for the refractory shell of sections subject to higher wear. For example, one or more sections of injection lance 10 may have refractory shells formed of the refractory composition described above, that is isopressed onto the center pipe, while one or more sections of injection lance 10 may have refractory shells formed of a refractory composition including a castable refractory material having regular wear-resistance properties. Thus, injection lance 10 may be assembled from at least one section having a refractory shell formed by isopressing, and at least one section having a refractory shell that is not formed by isopressing (e.g., casting). It is further contemplated that a single section of injection lance 10 may include a portion of the refractory shell formed of isopressed material, and a portion of the refractory shell formed of a castable refractory material.

[0054] It should be further understood that in certain applications, a refractory composition having a lower thermal conductivity than the refractory composition discussed in detail above may be located adjacent to the center pipe, to inhibit transfer of heat to the center pipe. In this regard, transfer of excess heat to the center pipe may cause it to fail (e.g., bend) during use.

[0055] It is contemplated that the geometry of refractory shells 60, 260, 360 and center pipes 30, 130, 330 may differ from the illustrated embodiment. In this

regard, alternative geometries may be used that allow joining of body sections 20A-20C and end section 120 (or end section 320) to form injection lance 10.

[0056] Assembly of injection lance 10 will now be described with particular reference to FIG. 1. Body section 20C is joined to body section 20B by threadingly attaching second end 46 of body section 20C with first end 38 of body section 20B, thereby providing a fluid connection of center pipes 30 of body sections 20C and 20B. In a like manner, body section 20B is joined to body section 20A, thereby providing a fluid connection of center pipes 30 of body sections 20B and 20A. Body section 20A is joined to end section 120 by threadingly attaching second end 46 of body section 20A with first end 138 of end section 120, thereby providing a fluid connection of center pipe 30 of body section 20A and center pipe 130 of end section 120. As indicated above, male end 70 of body sections 20A-20C is dimensioned to mate with female end 80 of body section 20A-20C, and male end 270 of end section 120 is dimensioned to mate with female end 80 of body section 20A. When assembled, body sections 20A-20C and end section 120 provide a continuous pathway through injection lance 10, defined by center pipes 30, center pipe 130, pipe 190, and porous nozzle tip 182.

[0057] Body section 20A is joined to alternative end section 320 in the same manner as body section 20A is joined to end section 120. In this regard, body section 20A is joined to end section 320 by threadingly attaching second end 46 of body section 20A with first end 338 of end section 120, thereby providing a fluid connection of center pipe 30 of body section 20A and center pipe 330 of end section 320. When assembled, body sections 20A-20C and end section 320 provide a continuous passageway through the injection lance for introducing a gas, or a gas and one or more powdered/granular metallurgical agents, into molten metal.

[0058] Injection lance 10 may have fewer or more body sections than shown in the illustrated embodiment of the present invention. In this regard, the number of body sections may depend upon the required length of injection lance 10, and the dimension of the mold used to form a refractory shell by isopressing. In a preferred embodiment, body sections 20A-20C, end section 120 and end section 320 have a length in the range of approximately 3 feet to 10 feet.

[0059] One embodiment of the present invention, as shown in FIG. 1, operates in the following manner. At least a portion of end section 120 of injection lance 10 is

inserted into molten metal, and a gas (e.g., argon) is forced into the other end of injection lance 10. The gas travels through the continuous pathway defined by center pipes 30 of body sections 20A-20C, center pipe 130, nozzle pipe 190, and porous nozzle tip 182. The gas is forced through porous nozzle tip 182 forming tiny gas bubbles that diffuse into the molten metal.

[0060] In an alternative embodiment of the present invention, end section 320 is substituted for end section 120. Accordingly, a gas, or a gas and one or more powdered/granular metallurgical agents, may be introduced into the molten metal in the following manner. At least a portion of end section 320 of injection lance 10 is inserted into molten metal, and a gas (e.g., argon), or a gas and at least one powdered/granular metallurgical agent (e.g., lime, calcium silicide, and ferromanganese), is introduced into the other end of injection lance 10. The gas, or the gas and at least one powdered/granular metallurgical agent, travels through the continuous passageway defined by body sections 20A-20C and end section 320.

[0061] In the event that a body section or end section becomes worn, eroded, or otherwise unsuitable for continued use, the section of injection lance 10 can be removed by threadingly detaching the section, and replacing the removed section with a new section, in accordance with the assembly process described above.

[0062] The refractory composition discussed above addresses several problems encountered with prior art injection lances to provide a longer lasting, more cost-effective injection lance. In this regard, the refractory composition of the present invention addresses the problem of cracking experienced when magnesia-carbon sleeves have been used in the slagline portion of an injection lance. Furthermore, the thermal shock and cracking problems of prior art injection lances has been addressed by the physical properties and adherence of the refractory composition, and the ability to embed anchoring members and other metal components into the refractory composition. The refractory composition of the present invention also provides improved wear characteristics, as compared to conventional castable refractory materials used in prior art injection lances. Furthermore, the use of isopressing for forming refractory shells for sections of the injection lance addresses the problems encountered with making large vertically-cast lances.

[0063] Other modifications and alterations will occur to others upon their reading and understanding of the specification. It is intended that all such

modifications and alterations be included insofar as they come within the scope of the invention as claimed or the equivalents thereof.